

at least partly responsible for the higher levels of health promotion services that table 4 shows that the paper, petro, and mechan groups provided.

Predominance of employees of one sex, the socioeconomic levels of the workforce, or management's response to mandatory pressure might also have contributed to variations in the extent and type of occupational health services provided.

Within the limitations of a cross-sectional survey, we were able to observe that medical services, at least up to mandated minimums, are probably available to most of the workforce in South Carolina. This type of survey does not permit conclusions as to the degree to which these services were established in response to regulatory pressures. The survey indicated that industrial management in South Carolina was not yet taking full advantage of the possible cost-benefits to be derived from offering the secondary level of occupational health services. Also, the national vogue for health promotion and physical fitness was not reflected in the services provided to workers in the State through their employment.

The type of study we conducted permitted observation of interindustry differences in both the level and the type of services, but the reasons for these differences must remain speculative. It is difficult to determine how relevant the findings are to other States. South Carolina is an OSHA Agreement State, but whether this has caused services to develop differently than in non-OSHA Agreement States is

not clear. A large proportion of the plants surveyed are subsidiaries of, or have relationships with, national corporations that have plants in many States, and these relationships may have reduced the influence of purely regional factors. It is of interest that Fielding (7) found levels of health promotion activity in California industry similar to those we observed.

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## The Three Mile Island Population Registry

MARILYN K. GOLDHABER, MPH  
GEORGE K. TOKUHATA, DrPH, PhD  
EDWARD DIGON, MPH  
GLYN G. CALDWELL, MD, MPH  
GARY F. STEIN, MD, MOH  
GUY LUTZ  
DAVID GUR, ScD

Ms. Goldhaber, Dr. Tokuhata, and Mr. Digon are with the Division of Epidemiology Research, Pennsylvania Department of Public Health—Ms. Goldhaber as chief, Nuclear Health Research Program; Dr. Tokuhata as director of the division and program manager, Three Mile Island Research Program; and Mr. Digon as chief, Special Studies Section. Dr. Caldwell and Dr. Stein are with the Chronic Diseases Division, Center for Environmental Health, Centers for Disease Control, Atlanta—Dr. Caldwell as deputy

director of the division and Dr. Stein as medical epidemiologist, Special Studies Branch. Mr. Lutz, who is now retired, was regional director of the U.S. Bureau of the Census, Philadelphia. Dr. Gur is associate professor of radiation health and radiology at the Graduate School of Public Health, University of Pittsburgh.

Tearsheet requests to George K. Tokuhata, DrPH, PhD, Division of Epidemiology Research, Pennsylvania Department of Health, P.O. Box 90, Room 1013, Harrisburg, Pa. 17108.

## SYNOPSIS

*Shortly after the March 28, 1979, accident at the Three Mile Island (TMI) nuclear plant outside Harrisburg, Pa., the Pennsylvania Department of Health, in conjunction with the Centers for Disease Control and the U.S. Bureau of the Census, conducted a census of the 35,930 persons residing within 5 miles of the plant. With the help of 150 enumerators, demographic and health-related information was*

collected on each person to provide baseline data for future short- and long-term epidemiologic studies of the effects of the accident. Individual radiation doses were estimated on the basis of residential location and the amount of time each person spent in the 5-mile area during the 10 days after the accident.

*Health and behavioral resurveys of the population will be conducted approximately every 5 years. Population mobility, morbidity, and mortality will be*

*studied yearly by matching the TMI Population Registry with postal records, cancer registry records, and death certificate data. Because the radiation dose from TMI was extremely small, any increase in morbidity or mortality attributable to the accident would be so small as not to be measurable by present methods; however, adverse health effects as a result of psychological stress may occur. Also, a temporary increase in reporting of disease could occur because of increased surveillance and attention to health.*

**E**ARLY ON WEDNESDAY MORNING, MARCH 28, 1979, a minor plumbing problem occurred in the cooling system of the Three Mile Island (TMI) nuclear plant outside Harrisburg, Pa. Normally this condition is easily remedied, but on this day the required interventions, both human and mechanical, were flawed. A series of "unlikely events" led to the shutdown of the unit 2 reactor, as thousands of gallons of radioactive water spilled within the plant building and the reactor core dangerously overheated (1-3). An estimated 2.5 to 10 million curies of radioactivity escaped into the atmosphere during a tense week of worldwide concern over the fate of the nuclear plant and its surrounding population (3,4). The TMI accident has been called the worst to occur in commercial nuclear power generation.

By the end of the first week, government authorities announced to a skeptical public that, although the situation could have been very serious, it had been brought under control. They stated that the radiation dose received during that week by persons living near the plant had been very small. The maximum possible dose to someone standing unprotected anywhere on the border of the plant site for the 10-day duration of the accident was estimated at less than 100 millirems (5), the approximate equivalent of 1 year's natural background radiation or of 3-5 chest X-ray exposures delivered to the whole body. The average likely dose to persons living within 5 miles of the plant was estimated to be 9 millirems, an amount similar to the radiation a jet plane passenger would receive from two roundtrip flights across the country (6). With respect to long-term effects on health from TMI radiation exposure, it was projected that among the more than 2,164,000 persons living within 50 miles of the plant, one excess death from cancer would occur over the lifetimes of these residents. (An estimated 325,000 of these persons will die from cancers unrelated to TMI.) The total number of excess morbid or mortal conditions re-

sulting from TMI radiation—including all cases of cancer (fatal and nonfatal) and genetic ill health for all future generations—was estimated as two (5).

Though the crisis passed, public apprehension remained. The public questioned the validity of the estimates of radiation dose to local residents and of the health risk from that dose. This apprehension was due, in part, to the general public's perception of radiation as being mysterious and dangerous, capable of causing cancer and other dread conditions. In addition, lay persons remained dependent on the "experts" to ensure safety in the management of nuclear power and to evaluate risks in the event of exposure. The "experts" had almost failed in the first case and were being questioned in the second.

Health authorities in both the Commonwealth of Pennsylvania and the Federal Government agreed that because confusion and uncertainty had surrounded the TMI nuclear accident from the beginning, and because the accident had been the first of its kind, the exposed population should be followed up and studied for many years to monitor any possible changes in physical and mental health (7).

## **Materials and Methods**

**Population data.** Within 3 months after the accident, a census of 35,930 persons living within 5 miles of the TMI nuclear plant was taken in a cooperative effort by the Pennsylvania State and Federal Governments. The primary agencies involved were the Pennsylvania Department of Health, the Centers for Disease Control, and the U.S. Bureau of the Census.

All three organizations contributed to the planning and operation of the TMI census. The Centers for Disease Control secured funds and provided onsite personnel: an epidemiologist, 2 managerial staff persons, and 20 team leaders (public health advisors). The Bureau of the Census provided ex-

pert consultation from its regional and national office staff, an onsite demographer, and onsite training of census enumerators. A retired regional director of the Bureau was brought in to oversee all data collection activities. The Pennsylvania Department of Health provided facilities as well as its own epidemiologist and numerous support staff—including 150 newly hired local enumerators—and assumed responsibility for all followup studies conducted on the census population.

The information that was collected during the census will provide baseline data for future epidemiologic studies of the effects of the nuclear accident. These data—known as the “TMI Population Registry”—include demographic information on each resident of the 5-mile area, such as name, address, age, sex, race, and a brief medical history of cancer diagnoses, thyroid disorders, radiation treatment or therapy, and prior exposure to ionizing radiation on the job. Pregnancies at the time of the accident were noted, and smoking histories were included for all teenagers and adults. In addition, each person’s daily travel in and out of the 5-mile area during the 10 days after the nuclear accident was recorded so that crisis evacuation patterns could be evaluated and TMI-related radiation doses estimated for each person in the registry.

By early June 1979, 150 enumerators had been hired and trained and were ready to collect data on the TMI population. On June 20, the enumerators began canvassing the 5-mile communities, registering each household, and conducting door-to-door interviews with one adult respondent from each household. The respondent provided information on himself or herself and on all other members of the household.

Registration and interviewing proceeded intensely for about 1 month. After 6 weeks, 92–93 percent of the population had been successfully interviewed, and most of the interview forms had been coded and edited by the enumerators themselves. When all the data were collected, the registry was estimated as 93–95 percent complete. Less than 2 percent of the households canvassed had refused to respond; less than 2 percent of responses had been unobtainable for other reasons; less than 2 percent of households had been missed during enumeration; and less than 1 percent had remained uncontacted because the residents had moved between the time of the accident and the time of the census.

In collecting and processing the data, the interviewers made every attempt to maximize coverage and minimize incomplete data. Households were

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visited up to four times in an attempt to find someone at home to be interviewed. If this failed, interviews were conducted by telephone. Once the interviews had been completed, the interview forms were reviewed several times for different purposes. If the forms were found to have missing or inconsistent information, callbacks to the household were made. In addition, several quality control measures were performed, including standard Bureau of the Census measures of “between-household coverage control” and “within-household coverage control” (8), before data were computerized and validated to eliminate sporadic and systematic errors.

The response of the TMI residents to the census was exceptionally good because of adequate media coverage and a strong sense of commitment from both enumerators and residents. The well-tested methods of the Bureau of the Census and the epidemiologic expertise available to the project further ensured a solid data base.

Complete descriptions and frequency distributions of all the variables in the data base are contained in another paper (9). Most variables were defined and coded as in the 1970 and 1980 U.S. Bureau of the Census reports. Missing values for each variable averaged about 1 percent. Several of the more important variables provided subject matter for special reports: analyses of the incidence of spontaneous abortion (10), prevalence of cancer in the TMI area before the accident (report to be released), and crisis evacuation (11).

**Household location and radiation dose data.** Some important variables were added to the data base after the TMI census was taken: location of residence (distance from TMI and direction) and radiation doses (“maximum possible” and “likely” whole-body gamma millirem doses) for each person in the TMI Population Registry. This work was carried out by the University of Pittsburgh’s Department of Radiation Health. Residential locations were derived from work maps of households canvassed during the TMI census and were plotted by hand onto a com-

puterized map of the 5-mile area. Individual radiation dose assignments were made on the basis of estimated time-dependent dose-rate distributions in the 5-mile area (12), combined with household location and individual whereabouts during the 10-day period after the accident.

**Post office update.** To maintain the followup registry, it was necessary to have a way of keeping in touch with registrants and obtaining vital data about them. With the help of the U.S. Postal Service, the Pennsylvania Department of Health devised a system to obtain annually the current addresses of persons in the TMI Population Registry without contacting the registrants directly. At about the same time each year, names and addresses of all persons in the registry aged 16 years or older are sent to the local post office for address verification and update (children under age 16 are assumed to move with their mothers). In compliance with postal regulations, the names are sent on computer-generated cards sorted first by zip code and postal carrier route and then arranged alphabetically by name. The post offices are obliged to respond, within 10 working days after the request for update is received, by supplying all relevant forwarding address information on file. Many post offices also correct spelling errors, indicate deceased addressees, and supply other helpful information.

Each year, new current addresses are added to the computerized registry file and followup codes are assigned accordingly. In addition, previous moves are recorded by storing the zip code from which the move took place and the year in which the move was ascertained. Up to 10 previous moves can be stored on the computer tape, allowing a systematic study of moving patterns of persons in the registry. A study of moving patterns during the first year after the accident has already been conducted (13).

## Plans for Analysis

**Link to death certificate listings.** Each year, the Pennsylvania Department of Health matches the TMI Population Registry against death certificate listings in Pennsylvania. When an appropriate match occurs on name, birthdate, and social security number, the cause-of-death information (both underlying and contributory causes) is extracted from the death files and added to the TMI Population Registry. This will allow analysis of deaths due to cancer, thyroid disease, or other causes that may be associated with low-level ionizing radiation or stress. Approximately

once every 3 years, the Pennsylvania Department of Health will match the TMI population registry against the National Death Index for those persons who moved and died outside Pennsylvania.

Periodically, age-adjusted TMI death rates will be compared with age-adjusted death rates in selected areas of the State. Age must be taken into account because TMI registrants will grow older with time, whereas comparison populations remain a cross section of the society at a given time.

**Link to cancer registry data.** Because ionizing radiation exposure has clearly been linked with cancer (14), an optimum followup program for the TMI Population Registry includes ascertainment of new cancer diagnoses after the TMI accident. On the basis of studies from Hiroshima and Nagasaki, where the average radiation exposure for survivors of the bomb blasts was thousands of times higher than at TMI, no measurable increase in cancer incidence in the TMI area has been predicted (5). Nevertheless, because of lingering public skepticism about estimates of the magnitude of the radiation dose, and because of voiced public concern about increased risk of cancer, it is important that the incidence of cancer among the TMI population be carefully documented. Given a reliable cancer incidence registry, this should not be difficult.

Before 1982, no statewide cancer registry existed in Pennsylvania; however, under recently enacted legislation, all hospitals throughout the State are required to report newly diagnosed cases of cancer to a central registry. Although the initial legislation was drafted before the TMI accident, the 14 south-central counties surrounding TMI were designated in 1982 as the start-up area for the Pennsylvania Cancer Registry. By 1984 or 1985, the cancer reporting system should become operative throughout the State.

Once the Pennsylvania Cancer Registry is fully operational, the Pennsylvania Department of Health plans to match the cancer incidence file annually against the TMI Population Registry. As with all "protected" State data, personal identifiers in both registries will be kept completely confidential. Data will be released only in aggregate form.

**Special health surveys.** Approximately every fifth year, the Pennsylvania Department of Health will conduct special health surveys of the TMI Population Registry. Either the total population of the 5-mile area or a representative sample will be employed, depending upon the nature of the survey.

Questions about reproductive experiences, major morbidity, and psychological and emotional problems experienced since the accident will be asked. The surveys will also provide a means of ascertaining opinions and attitudes of the public toward TMI and toward nuclear power in general. (For followup of infants exposed *in utero* to the accident, a special TMI Infant Registry has been devised from another data source, the TMI Pregnancy Outcome Study (15), as a sampling frame for studying potential long-term health effects.)

## Discussion

We believe that followup of the TMI accident is of interest to both the scientific and the lay communities and has broad implications for the future of commercial nuclear power in this country and elsewhere.

Since the 1950s, when nuclear power was first introduced, decisions about the building and operation of nuclear powerplants had been made by experts, with little input or resistance from the general population. When, after 30 years of relative public confidence, the first major commercial nuclear accident occurred, difficult but important questions were raised about the safety of nuclear energy. We are hopeful that the upsurge of public debate will help close the knowledge gap between the experts and the public, as benefits of, risks from, and fears about nuclear energy become better understood and placed in proper perspective.

Scientists already have a substantial amount of knowledge about the biological effects of ionizing radiation (14,16). From Federal funds alone, nearly \$5 billion has gone into research involving human and animal studies (17,18). Because of this massive effort, more is known about the effects of radiation—in terms of cancer, birth defects, chromosome breakage, and other outcomes—than about the effects of any other environmental hazards (such as chemical carcinogens) on the human organism.

There is general agreement among health physicists and radiation biologists about the effects of high doses of ionizing radiation, but the consensus is not as strong about the effects of low doses—especially doses below 10 rems (14,17,19–22). The question most often raised is whether the same dose-response relation seen with high doses also occurs with very low doses, whose health effects are difficult to measure. Although this is an important scientific question, the various possible answers to it may yield relatively minor differences in terms of

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public health—that is, the actual excess number of mortal or morbid conditions in a population. However, among persons who are skeptical of any calculation involving radiation, this controversy over the effects of low doses can evoke much apprehension.

One major purpose of the registry is to document, for a large number of human subjects, the effects on health of the low-level radiation exposure occasioned by the TMI accident. On the basis of previous studies of biological effects of ionizing radiation and the various dosimetric studies conducted after TMI, it is unlikely that any extra cases of cancer or genetic disorder will be detectable among the 35,930 persons who lived within 5 miles of TMI at the time of the accident and shortly after. Should increased morbidity or mortality among the TMI population be found that cannot be explained by sociodemographic or other known intervening factors, exposure to psychological stress and its sequelae could be implicated.

Several investigators have studied stress among the TMI population (23–25). They found that considerable levels of stress were experienced during the 2-week crisis period and that moderate levels of stress were maintained for many months afterward. Because the cleanup of the plant will continue for several years, it is likely that stress will remain with the TMI population for years to come. We believe that it is important to continue to study psychological stress as an unavoidable outcome of a nuclear accident.

Earlier studies showed that persons who evacuated the 5-mile area during the accident had higher stress indices, when evaluated several months later, than persons who did not evacuate (23). Thus, both TMI-related stress and TMI-related radiation dose will be important to consider when the results of data analysis are interpreted with respect to health effects. Other intragroup (internal) comparisons of various

*'One major purpose of the registry is to document, for a large number of human subjects, the effects on health of the low-level radiation exposure occasioned by the TMI accident.'*

health parameters, as well as comparisons with control groups selected from communities in Pennsylvania with sociodemographic characteristics similar to the TMI population, will also be made. As indicated earlier, age and other factors will be taken into account, particularly when the TMI population is compared with cross-sectional control populations.

It is possible that spurious increases in morbidity may occur because of heightened public awareness and increased surveillance activities. The TMI population may perceive itself as being at greater risk of diseases and, therefore, may report symptoms of disease to physicians and researchers earlier and more often than usual. If this occurs, a temporary increase in cancer incidence, for instance, may be observed. However, earlier reporting will not necessarily lead to increased mortality and, after a few years, such fluctuations in morbidity and mortality statistics should stabilize. This is another reason why it is important to conduct studies for a period of many years to recognize any artifact that may occur in reporting.

As objective information accumulates from the TMI Population Registry, the lingering uncertainty from the TMI accident should diminish and, perhaps, future decisions about nuclear power as a domestic source of energy can be more readily and confidently made.

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## New Partnership for Health? Business Groups on Health and Health Systems Agencies

ROBERT C. BRADBURY, PhD

The paper is based on Dr. Bradbury's presentation at the 110th annual meeting of the American Public Health Association on November 15, 1982, in Montreal. He is director of the joint Clark University/University of Massachusetts Medical School Health Administration Program.

Tearsheet requests to R. C. Bradbury, PhD, Graduate School of Management, Clark University, 950 Main St., Worcester, Mass. 01610.

### SYNOPSIS .....

*The experience of the Central Massachusetts Health Systems Agency (CMHSA) and the Central Massachusetts Business Group on Health (CMBGH) demonstrates the feasibility of cooperation between HSAs and BGHs. Objectives and strategies of the two groups in carrying out community health planning and working for health systems change are compared.*

*Nearly two decades of government-sponsored community health planning programs, first through comprehensive health planning agencies and then through HSAs, have had less impact than many had anticipated because neither the technical nor political basis for such planning was sufficiently established. The CMHSA experience is typical, although it is credited with developing a hospital systems plan that is based on sound planning methods and sta-*

*tistical data. It is in the implementation of plans that the CMHSA has made slow progress, reflecting its inadequate community power base.*

*The CMBGH, 1 of more than 90 groups that have developed recently across the country to attack high health care costs, was formed in 1981 by business leaders to address these rising costs. The principal strategy adopted by the CMBGH involves fostering a competitive health care market by creating a critical number of competing health plans. The providers in each plan will then have incentives to provide effective care in an efficient manner to keep the premium competitive and attract enrollees.*

*Cooperation between the CMBGH and CMHSA is based on each organization's emphasizing its strengths. The CMHSA's data base and analyses have been the primary resources used by the CMBGH to identify problems. Each organization has developed its own set of goals and objectives, while keeping in mind those of the other organization. The CMBGH adopted a subset of the CMHSA's goals—those that focus on hospital capacity and utilization. Although the CMHSA's regulatory strategies differ greatly from the CMBGH's competition strategies, they do not necessarily conflict. Actually, each organization is supporting the other's strategies without deemphasizing its own. The CMBGH currently has a decisive advantage over the CMHSA in implementing activities because the business leaders are an integral part of the community power structure. Also, their companies' willingness to offer additional health plans to their employees is the prime incentive to develop such plans.*

**I**N 1966 THE COMPREHENSIVE HEALTH PLANNING and Public Health Service Amendments Act (Public Law 89-749), referred to as the Partnership for

Health Act, called for consumers and providers of health care to join forces to plan improved health systems. In the more than 15 years of federally